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Women's tidal power plant Forty candles for Kislaya Guba TPP

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Abstract

Tidal energy has been used for centuries. Tidal current and rise and fall of tides were both put to work. They provided power for flour mills, saw mills, breweries, etc. Tide mills dotted several regions of Europe from The Netherlands to Spain and from Wales to England. Immigrants brought the technique to the "New World" to the United States and Canada. But they could not withstand the development of more efficient power production and faded away. Though some subsisted well into the 20th century, most of those still in existence offer mainly a tourist interest. However, they may well be considered the forerunners of the power-generating tidal power stations. These are not numerous—except mini plants in China—but with the price of oil soaring a renewed interest as developed. Of all existing stations, the Kislaya Guba station has not the largest; but the only one completely built by women, and it celebrates this year its 40th birthday.

Keywords: Artic site; Bulb turbine; Construction method; Kislaya characteristics; Rance TPP; Tide mills

Contents

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1. Introduction

Elisabeth Mann Borgese encouraged one of the authors, from the earliest PIMs Convocations (Pacem in maribus) to present papers on the contributions ocean energies could make to reduce reliance on fossil fuels and to cut down on CO_2 emissions into the atmosphere. If it would be improper to call her, therefore, a visionary, at least she should be credited with endorsing an approach, albeit complementary, whose day has come.

She was and has been on the same wave length as Leonid Bernshtein who pleaded convincingly until his demise (2006) for his country—whose tidal energy resources are immense—to tap ocean energy. The literature dealing with the topic is voluminous and goes back centuries with contributions by Veranzo, Mariano, Leonardo da Vinci, and, closer to us, Bernard Forrest de Bélidor. A patent was even taken out in the 19th century. Though timid efforts were actually made and some mini-plants are reported to have functioned—not all to produce electricity—it is only in the first quarter of the 20th century that actually some sizeable wharves were started, e.g., in Quoddy (USA) and Aber W'rach (Brittany, France) (Figs. 1 and 2).

1.1. Tide mills

The historic value of tide mills is being recognized, perhaps buttressed by possibilities of reviving their use towards modern versions. Some have indeed been put back into working conditions and the Southampton one is now "a working museum" [1]. Changing attitudes towards industrial archaeology [2] and growing concern for our maritime architectural and environmental heritage have also influenced the present trend towards the study and conservation of these remains, proof of the ingenuity of our forebears.

So far, the study of tide mills, on both sides of the Atlantic, has been very uneven. In Britain, Rex Wailes published the first detailed study of the mills of England and Wales in 1941 [3]. Tide mills are first mentioned in the Persian Gulf. In the 10th century, the Arab geographer, Al-Magdisi Shams al-Din described the mills found at Bassora (Irak), on the Tigris–Euphrates delta, explaining how water turned the wheels as it flowed back to the sea [4]. The earliest known European mill was built in southern England between 1066 and 1086 at the Dover port entrance [5]. Mills' numbers increased steadily throughout the Middle Ages: e.g., Zuicksee (the Netherlands, 1220), Veulves (Normandy, 1235), Esbouc and La Nive (Basque Country 1251 and 1266), Castro Marim (Iberian Peninsula, 1290) [6].

The Great Voyages of the 15th century affected the evolution of tide mills, especially near major ports (Lisbon, Cadiz). Across the estuary of Lisbon, there were 27 mills, and

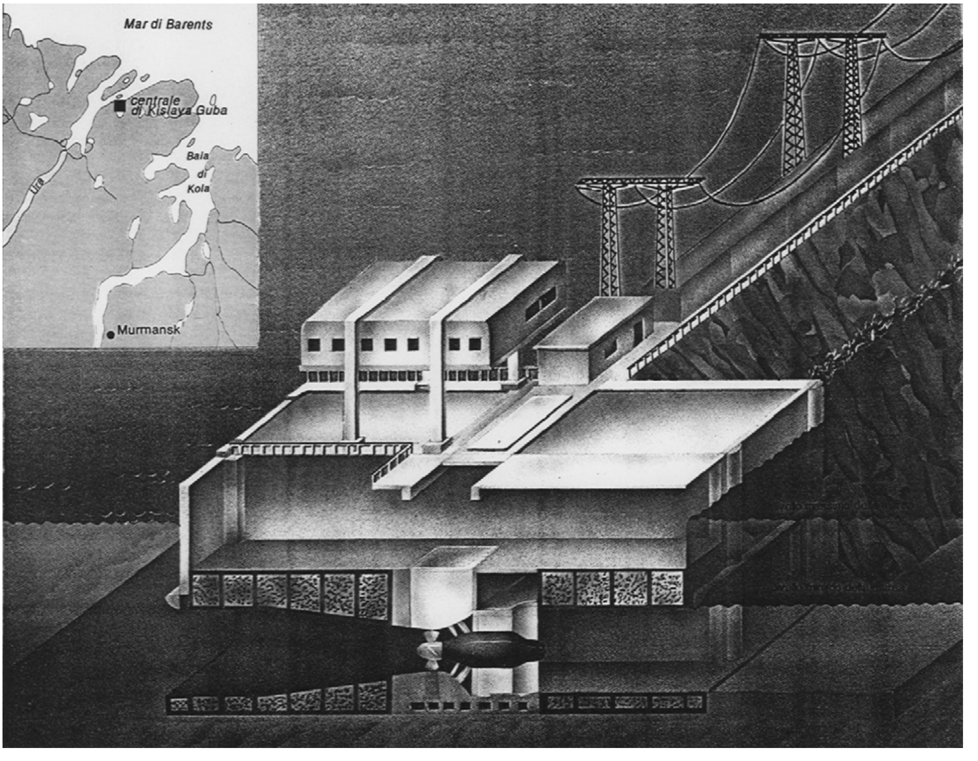

Fig. 1. Location map of the Kislaya TPP and artist's view of TPP.

some hundred mills operated in the Tagus estuary. The development of saltpans led to the establishment of several new mills in the course of the 18th century [7]. In 1613, the French built the first tide mill in North America at Port Royal (Nova Scotia). Dutch colonists were among the first to build such mills in the United States; the Brooklyn Mill is one of the few still standing but a group of interested people are attempting to restore some in Maine (USA) and New England. On the shores of the Caribbean several mills have been recorded (e.g., Surinam); the mills of the Lesser and Greater Antilles were used for sugar cane processing [8]. The 18th century also saw the establishment of more complex installations using tidal energy. In Britain, several were still functioning at the beginning of the Second World War [9]. By 1950, most had closed or been abandoned. Bauchet mill did not close down until 1980. In Spain and Portugal, a few mills were still functioning in the sixties.

In all, over 800 mills were built on both sides of the Atlantic and the North Sea, and over half in Europe. About 300–350 mills were built on the coastal stretch between Canada and Georgia (USA) with 150 in Maine and Massachusetts (USA).

A tide mill comprises the mill proper, outbuildings, a dyke and a pond. The workings of a classic mill are simple. At high tide seawater flows into a pond, protected by a dyke, through a sluice gate that closes automatically, under pressure from the water accumulated in the pond, as the tide begins to withdraw. The water flows out of the pond through one or several narrower gates and, in so doing, turns the hydraulic wheels. Dykes are built

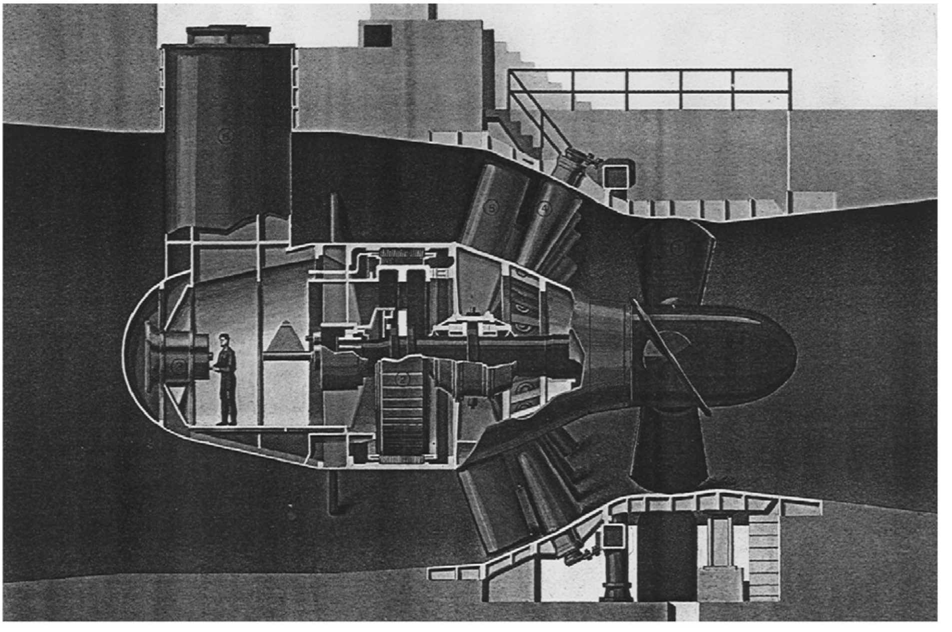

Fig. 2. Interior view of the bulb-type turbine.

along a single continuous line, which may be straight or curved depending on the nature of the coastline and the degree of exposure. Their length and width varied considerably.

Dykes have one or more openings formed by automatic, hinged gates through which seawater flows in at high tide. The size of ponds varies considerably since it depends on the coastline, the position of the Dyke and on the tidal range. Some mills have several

communicating ponds thereby providing a longer working time for the mill, about 15 h in all, as water flows from one pond to the next.

The purpose of the exit gates in single-effect mills is to direct water accumulated in the pond during the flood tide towards the hydraulic wheels during the ebb tide. Their number depends on how many wheels are to be turned. The 1809 census carried out in Brittany in 1809 showed that 80% of the 6450 wheels were vertical, and only 20% horizontal [10]. The number of wheels varies from one to three. The wheel shafts, of wood and iron, varied considerably in size.

The mill itself may be built in the middle or at either end of the dike, the exact place being usually determined by the topography and/or hydrology. Industrial mills, however, are usually built at one end of the causeway as this offers easier access. The architecture of tide mills is largely comparable to that of water mills. From the mid-19th century onwards, industrial mills could have three, four and even five storeys.

On the whole, tide mills were used for grinding grains and complemented windmills [11]. Between 1823 and 1828, the Cadiz (Spain) mills ground grain to feed the French occupation forces. They were also put to other uses: fresh water pumping, iron-slitting mill, rasping and chipping dyeing woods, manufacture of tobacco stems, provide power for breweries, copper smelting works, grinding of spices and grist mills. In Brittany, several early mills were transformed and used for flax, converted to paper mills, saw mills and carpenters' workshops and even used for the manufacture of ice. One mill was used to grind kaolin, while mills situated within saltpans were used for washing salt, while others were used in drying up of polders (the Netherlands).

Mill dikes, when not partly or totally destroyed, have been cemented, raised or widened in order to make way for new roads. They can also serve for the construction of houses. The most serious problems are due to the deterioration of millponds. Since they are no longer filled and emptied with every tide they have a tendency to naturally silt up. Silt and vegetation soon invade a large sector of their surface area.

1.2. The survivors

A certain number of mills have been saved from destruction or total ruin by being converted into dwellings, antique shops, restaurants and other uses. Unfortunately, such conversions often lead to the total disappearance of the inner machinery of the mills, while the hydraulic wheels fall into disuse and gradually rot. In some instances by being restored or turned into museums, mills become tourist and cultural attractions. The tide mills still at work in the Rance River estuary had to be removed when the tidal power plant construction started.

2. The need for renewable energy

Economics, supply, environmental and ecological outfalls are as many reasons to turn to the sea for additional sources of energy. Some voices predict that oil and gas supplies are being rapidly depleted and that by mid-21st century we may well run out of gas and oil. Climate changes, *n 'en déplaise à certains politiciens,* are caused by Man and reefs and glaciers are disappearing, CO_2 *oblige*. The problem is no longer a matter for just scientists to worry about, it has huge social outfalls. Extreme climatic conditions—and famine—are the cause of the death, annually, of 160,000 people.

Heat waves are responsible for the deaths in 2003 and 2004, in Europe of more than 30,000 people. The climatic changes make no difference between rich and poor, North and South.

But is it really worth efforts and investments to extract a modest quantity of energy from the oceans? It has been argued that if the potential of the oceans is huge, the amount that actually can be obtained is small. But is it really? For those who love statistics, female engineer and oceanographer Stephanie Merry, cites an estimation made a year of so ago, that one per thousand of the global ocean energy resource would suffice to power the entire world five times over [12].

Some technologies have already attained maturity (tidal power 1966, marine winds), others are beyond the try-out stage (wave harnessing, Portugal 2006), others are still in their developmental stage (marine biomass).

3. Many plans, no achievements

There have thus been proponents of harnessing the energy of the tides for many decades. As a matter of fact, we are nearing the one hundredth anniversary of the first European attempt at building a tidal power station on the Brittany coast, on the Aber Wra'ch. It failed for monetary motives, not technological ones. Indeed, the stock market *krach* of the late 1920s hit the project broadside. The same reasons doomed Franklin D. Roosevelt's undertaking at Passamaquoddy; only there it was the determined opposition of the local power companies that torpedoed the undertaking that was on its way. The project was not condemned, funds were simply cut off. Lobbying "*oblige*". The electricity companies feared for their *de facto* monopoly and guaranteed profits.

Capital investments seem to have been the brake that held back any tidal power station in France and in Great Britain for over the first 50 years of the 20th century. Had the Welsh project gone through—in the mid 20th century—it would have paid for itself very long ago. Piquant anecdotes surround the launching of the French plant on the Rance River near Dinard and Saint-Malo where Brittany and Normandy meet. It took a fellow like Charles de Gaulle to give the go ahead. That was 40 years ago. Some may challenge the "first place" claim of the "Rance" and allocate it to the seldom mentioned Boston and Bremen harbor plants, or even one in China.

The Rance River plant has been a success, even if many of its for the times revolutionary features are no longer on the forefront of technology and construction. Cofferdams have yielded to module construction. Bulb turbines can be replaced by Straflo (straight flow) ones. Low head turbines multiply the number of suitable sites. Bi-directional generation does not appear to be a bonanza. Pumping operations may be dispensed with. The Rance River Plant has had a few "off-springs" but not as many as one may have expected or at least hoped for. Inexpensive hydrocarbons are on the forefront of the reasons for the tidal power development slumber.

Russia, Canada and China are the only countries where plants were built, some on the Rance model, others using modified versions: all on a small scale. Yet, Korea is currently contemplating a plant that would dwarf the Rance. As the corks pop and the 40 candles are lit for both the Rance and Kislaya, tidal power climbs back into the news. Doubtlessly because of the high cost of other power generation systems and fuels, and additionally because of vastly improved technology. Controversy about nuclear power slowed down expansion, even continued use (Sweden) of the generation.

But there is another facet of the 21st century tidal power scheme. The plants proposed were all based on the up and down movement brought about by the tides. Now considerable interest has been generated for the to and fro tidal current (tidal stream), apparently less capital intensive, an interest particularly keen in Great Britain. Though there are some claims of a small tidal current station having once functioned on the Northern Iceland coast, there is a power generating plant on the East River in New York City. Is that the future of tidal energy tapping, or will barrages be the answer, or will both tide-induced movements develop parallel?

4. Women engineers built Kislaya

Bernshtein gathered a team of determined female engineers and set out to build Russia's first tidal power plant. Support from the Soviet authorities appears to have been at best lukewarm, even though publicity brochures published at the time mentioned such gigantic works as plants on the Sea of Okhotsk and the turning around of Siberia's river giants. They took the Rance River as a prototype, but accepted additional challenges: they showed the feasibility of siting a tidal power plant in a harsh climate, under Arctic conditions, and that construction costs, a major deterrent to tide energy harnessing, could be substantially cut down.

4.1. The site

The Kislaya plant is close to the White Sea that has a potential of 16 million kW. It is on a narrow inlet, only 40 m wide and 3–5 m deep, wherethrough water gushes at high tide at a speed of 4 m/s. The dam takes advantage of the narrow squeezed between 40 m high cliffs. The water depth is 35 m and the water surface 1.1 km^2. The average tidal amplitude is 2.5 m.

The site was prepared by removing rock by underwater blasting and loose rock removal, using a clam-shell-type crane. An excavation of some 25,000 m^3 was thus created. Next a sand-and-gravel bed was put in place.

4.2. The powerhouse

The powerhouse, best described as a concrete box, constitutes the closure. Only 36 m long, it is 18.3 m wide and 15.35 m high. The frost-resistant concrete was made of sulfate-resistant cement, with additives, quartzic sand, and hard igneous rock aggregates. The "box", built riverside near Murmansk, is made up of pre-cast concrete cellular units. The caissons were floated to the plant's site and sunk into place. Thus, the builders could dispense with cofferdams.

The powerhouse includes floorings and walls, penstocks and foundation slabs. The open bottom water outlet and open spillway are accommodated inside the powerhouse.

The turbines are of the bulb type—used at the Rance Plant. The runner diameter is 3.8 m. The turbines' and the generator's rotation speed are respectively 69 and 600 rpm.

4.3. The dam

The basin was closed off using TNT charges. Keeping the structure in place once it has been sunk was managed by filling empty cells with sand, adding heavy fuel oil to

waterproof and increase weight. To insulate the structures, glass fabric-reinforced foam epoxy resin panels line the concrete; the panels, 50–700/900 mm sheets are glued unto the sides by foam injection. Protection against corrosion and biofouling is attained by application of a dual coating of vinyl chloride paint—on the exterior—and epoxy tar—on the interior. The steel blades anchoring the structure, those of the turbines, and the steel of the vertical lift gates received cathodic protection. All in all, and allowing for the different climatic conditions (ET type in Murmansk area), there are many differences between the Rance River, that served as the basic model, and the Kislaya Guba plants.

Transportation of the ‘‘modules’’ or ‘‘units’’ was an approach previously taken when constructing breakwaters, lighthouses, locks and underwater tunnels. But there were ‘‘novelties’’ involved: its application to a hydraulic plant and the design of a ‘‘floating’’ platform. It has been used during the construction of the civil works of the Dutch Delta Plan and with some drilling platforms.

5. The United Kingdom and the marine renewable energy ‘‘Paysage’’

Air pollution, Global Warming, Climate Change and Dependence on Foreign Fossil Fuels now that domestic offshore supplies are dwindling, compel an earnest search for ways to close the energy gap and abate the nefarious effects of oil- and gas power. These have led the United Kingdom to endeavor to become a world leader in marine energy harnessing and to develop devices to power home and industry with wave and tidal power. There is an obligation for licensed English and Welsh power suppliers to provide electricity from renewable sources. Wind power, including offshore wind power, is among these. As a matter of fact emphasis has been placed on such wind farms, placing England and Wales in second place and Denmark first, with Scotland a leader in efforts and trials to implement tidal and wave energy harnessing schemes. Results are modest but encouraging. Quite a reversal for a country that has dragged its feet for more than a half century in regards to tidal power.

Efforts to enroll public support and to inform planners are buttressed by a campaign—the ‘‘It's Only Natural’’—that received a funding of £200,000 (about $320,000, €240,000). The British seem to believe that tidal stream generated power is the source of the future. SeaFlow® and SeaGen® are among trial systems that hold much promise. It is a bit surprising that some find the barrage plants environmentally unacceptable, without, however, making clear why they are at odds with what has been believed since the construction of the first Tidal Power Plants [12]. The US Energy Information Administration similarly provides encouragement but less forcefully and with less incentives.

6. Closing word

The total world resource for river hydro-plants, tidal and wave was estimated, in 1995, at 6000 GW by Duckers. Of these, 277 TWh of tidal power are found in the former Soviet Union, 20 in Argentina (San José Gulf), 17 each in the Severn River location (United Kingdom) and Turnagain Arm (Alaska). The Gulf of Cambay (India) and Cobequid Bay (Canada) could provide respectively 15 and 14 TWh. Bernshtein and Usachev (1997) reminded, on the occasion of the 30th anniversary of the TPP at Kislaya Guba, that Russia has a 17 million kW capacity and could transfer to the combined European power system

50 TWh per year and the proposed Tugur station could add a capacity of 8 million TWh/year utilizable by the coastal regions of the Russian Federation and Japan. He pointed out that if the American proposal of constructing a combination transport and power tunnel under the Behring Strait would ever materialize, a Penzinskaya TPP could be part of the complex with a capacity of 87 million kW. The potential of China is commonly overlooked, even though it attains 110 million kW. Five hundred bays in seven provinces share this resource: Tchekian, Shantoung, Kouandtong,, Iangsou, Hopei and Kianing. Duckers reviewed low head hydro-electric schemes and drew parallels with tidal power plants.

Retiere has examined repeatedly the environmental impact of the Rance River TPP and came to the conclusion, based on 20 years of operation, that the construction phase, during which the estuary was isolated, proved particularly environment damaging. However, once the plant was put into operation, a diverse flora and fauna established themselves. Their grouping into ecological units and their inter-relationships, show a varied degree of biological adjustment. The operating conditions of the plant influence the fragile new ecological equilibrium, even though migratory organisms are able to pass through sluices and turbines. Little quantitative data is available that covers the pre-barrage situation. The comparisons of species distribution are thus based upon the known penetration into the estuary when there was no barrage (Little & Mettam) [15]. Though this author does not share the viewpoint that the reason for the small number of TPP is to be attributed to environmental concerns—in his view the reasons are predominently economic-one will agree that EIAs are useful tools to identify the impacts, and indeed applications of modern appropriate technologies might help abate the objectionable effects of a tidal power plant (Salequzzaman) [16].

The Severn River is probably the tidal river which has been most thoroughly studied, and the most often as well, with an eye on building a TPP. It has also been shown that had a plant been built after WW II, it would have quite long ago paid for itself. Because of environmental effects of a barrage, and no doubt the economic aspects of any project, no TPP has ever been even started. Fry (2005) has described alternatives to a TPP-with-barrage. Among these tidal lagoons schemes have been proposed and so has the modest utilization of the tidal stream (tidal current) [14].

At one time, the powerful rulers of ever-warring European countries proved unable to end a conflict and sign albeit a truce. It were their female relatives that spelled out and signed, in their stead, the treaty known as *La Paix des Dames* [The Ladies' Peace] [13]. Ladies built a tidal power plant. Ladies added their voice to that of the advocates of using marine renewables. It is probably that of wisdom.

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